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**Level Set Surface Editing
Operators**

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Barr**

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Computer Science Department
California Institute of Technology**

Outline

- **Problem statement**
- **Short intro to Level Set Models**
- **Surface editing framework & operators**
- **Two editing sessions**
- **Wrap up**

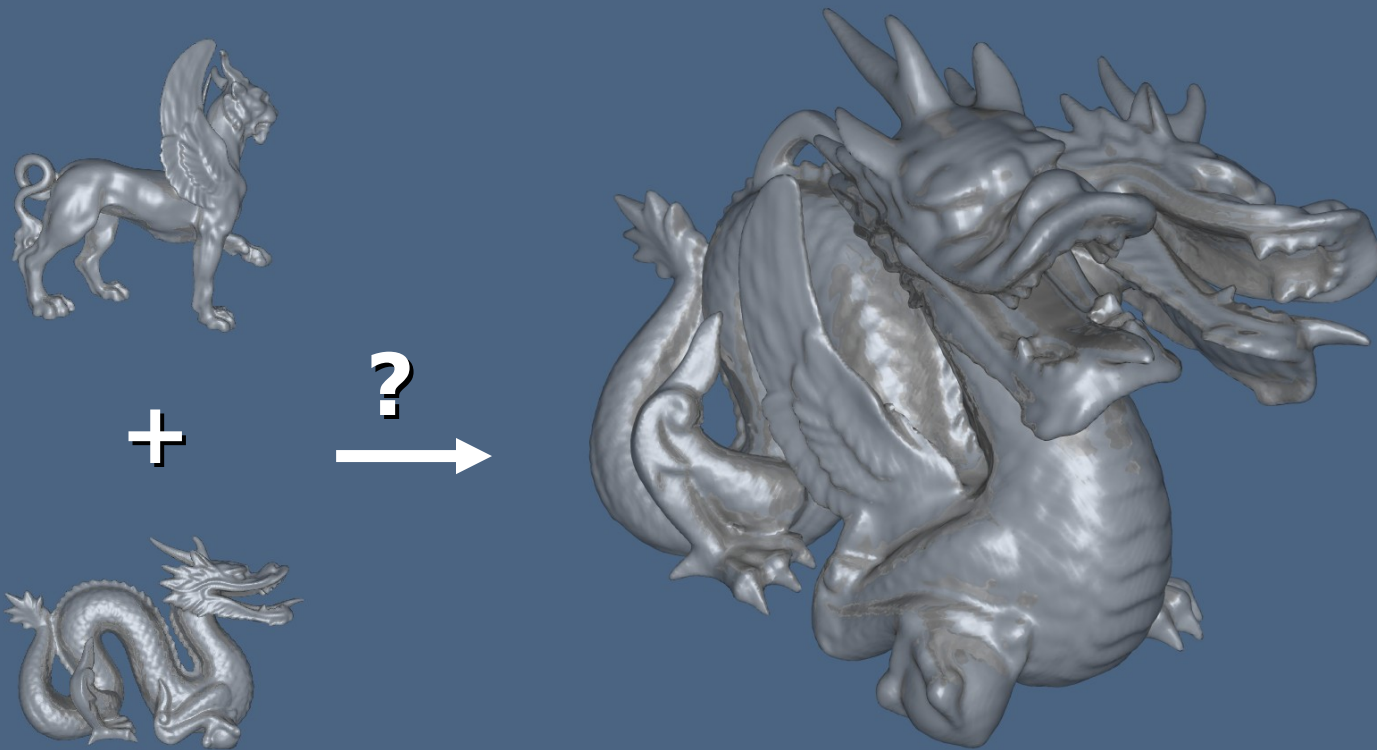
Problem Statement

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Problem Statement

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Contributions

- **Design LS surface editing framework**
 - Single representation and numerous tools
- **Definition of new LS surface editing operators**
 - Automatic blending along intersection curves
 - Spatially constrained smoothing and embossing
- **User control over local surface properties**
- **User control of inward/outward surface movement**
- **New techniques for localized computation**

Level Set Models

Implicit surface

Iso-value

$$S(t) = \{x(t) \in \mathbb{R}^3 \mid \varphi(x(t), t) = k\}$$

[Osher & Sethian 1988]

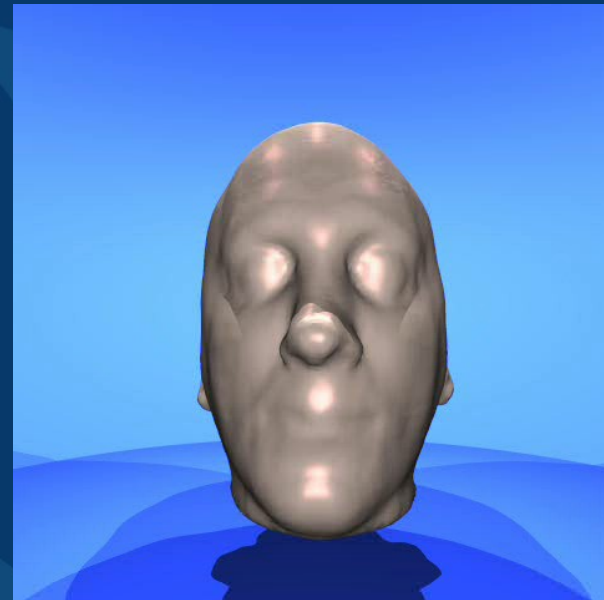
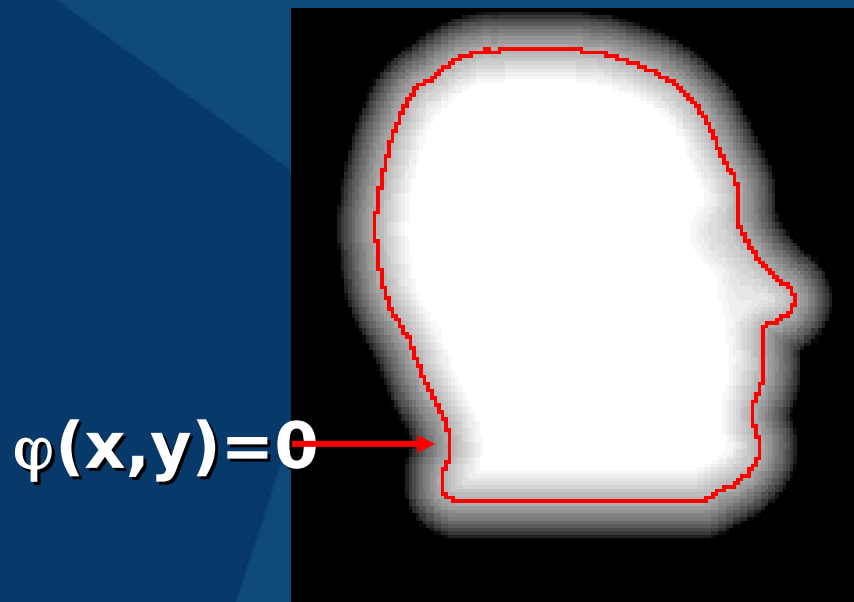
Level set function $\varphi: \mathbb{R}^3 \times \mathbb{R}^+ \rightarrow \mathbb{R}$

Speed function

$$\frac{\partial \varphi}{\partial t} + \vec{\nabla} \varphi \cdot \frac{dx}{dt} = 0 \quad \Leftrightarrow \quad \frac{\partial \varphi}{\partial t} = - \frac{dx}{dt} \cdot \frac{\vec{\nabla} \varphi}{|\vec{\nabla} \varphi|} \equiv \Gamma(x, \varphi, \dots) |\vec{\nabla} \varphi|$$

How Level Sets Work:

- Initialize φ as regular 3D sampling of signed distance function to initial geometry
- Propagate the time-dependent level set equation until convergence (steady-state)
- Surface is defined from zero-crossing of φ



Advantages of Level Set Models

- **By construction, produce closed, non-self-intersecting surfaces**
- **Easily change topological genus**
- **Free of mesh connectivity and triangle quality issues**
- **No need to re-parameterize during deformation**

Disadvantages of Level Set Models

- **No inherent parameterization ?**
- **Computationally expensive ?**
- **Cannot control genus ?**
- **Cannot represent fine, sharp features ?**

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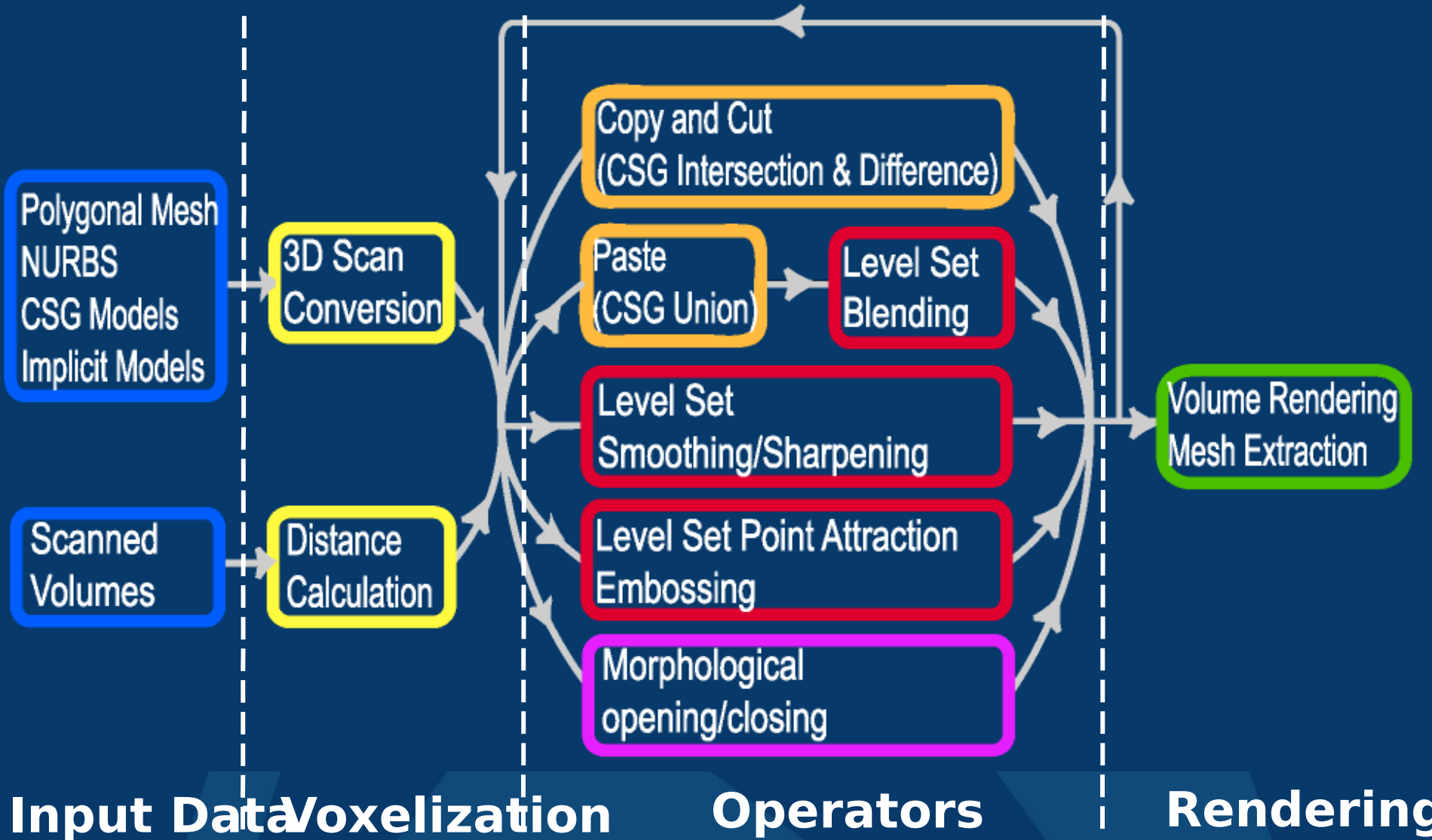
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 - True, but [Pedersen 1995, ...]
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 - Not true: [Han *et al.* 2001]
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- **Computationally expensive ?**
 - Not true: [Adalsteinsson & Sethian 1995]
- **Cannot control genus ?**
 - Not true: [Han *et al.* 2001]
- **Cannot represent fine, sharp features ?**
 - Not true: [Friskin *et al.* 2000, Kobbelt *et al.* 2001]

Level-Set Surface Editing Framework

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Speed Functions Building Blocks

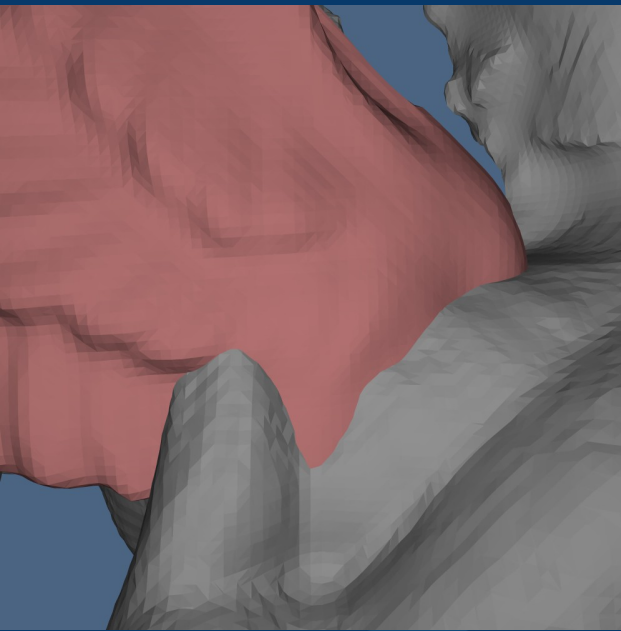
$$\frac{\partial \varphi}{\partial t} = \Gamma(\vec{x}, \varphi, \dots) |\vec{\nabla} \varphi|$$

Speed function
 $\Gamma = D_q(d) G(\gamma) F(\gamma)$

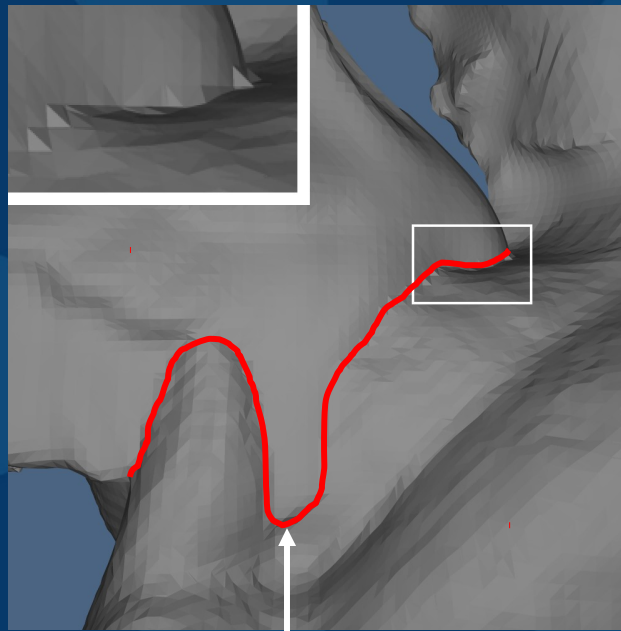
- **Distance-based cut-off function**
 - Regionally constrains speed function
- **Geometric property filter function**
 - Provides user control of local geometric properties
- **Function of geometric measure**
 - Maps geometric properties to surface speeds

Level-Set Blending

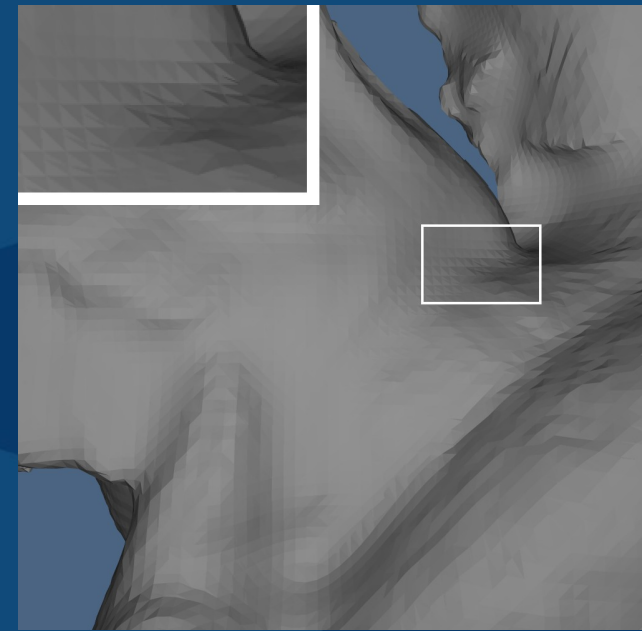
Position



Paste (CSG Union)



Blend



$$\Gamma_{blend} = D_c(d) G(K) \alpha K$$

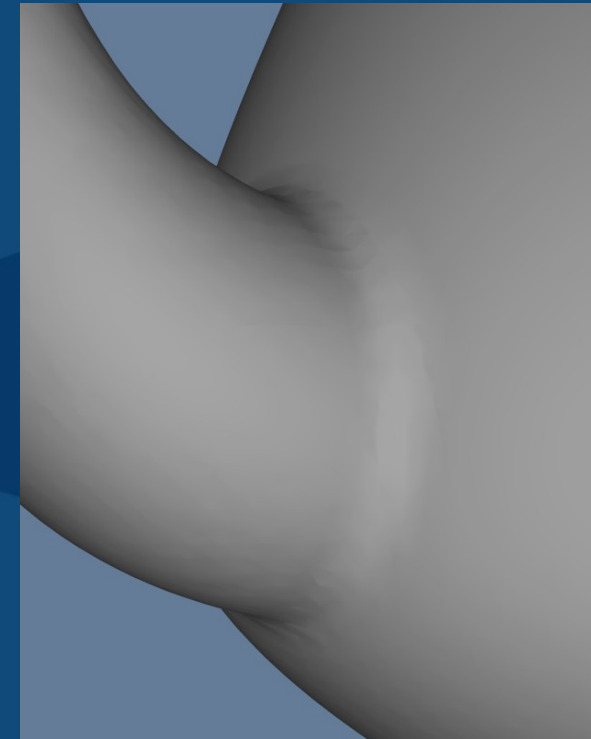
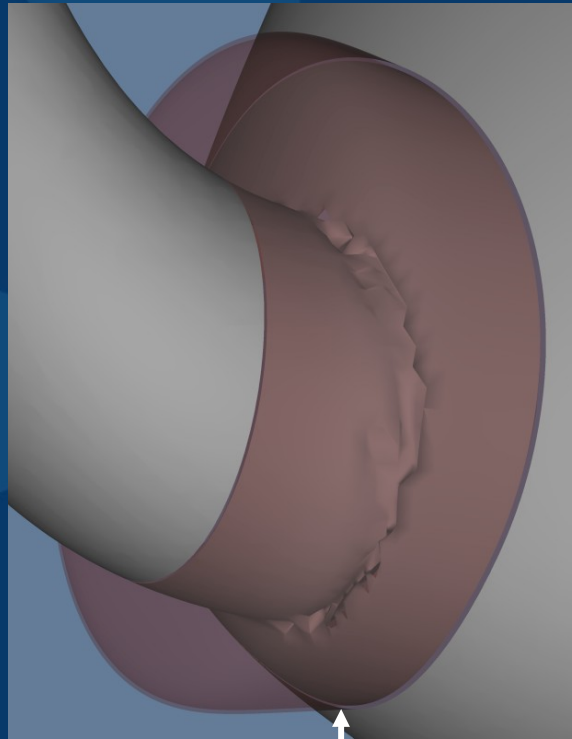
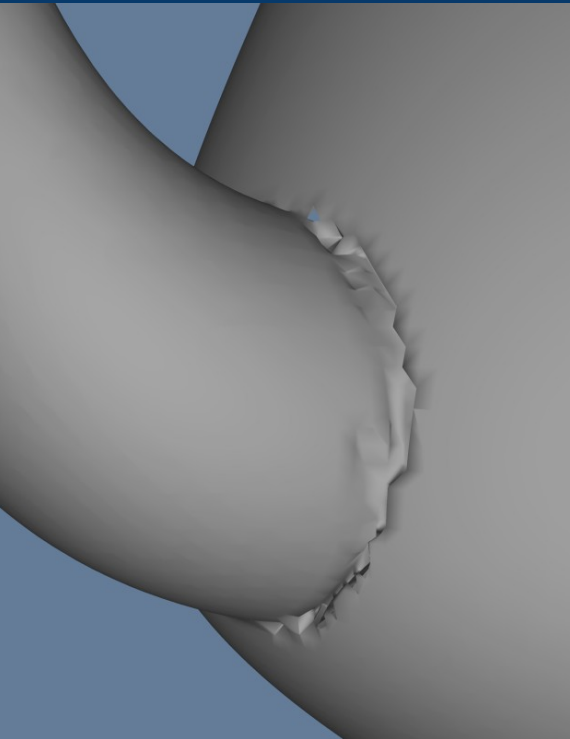
distance \downarrow curvature

cut-off func. \uparrow filter func. \uparrow

Localized Smoothing

Teapot Spout

Regional constraining Material added

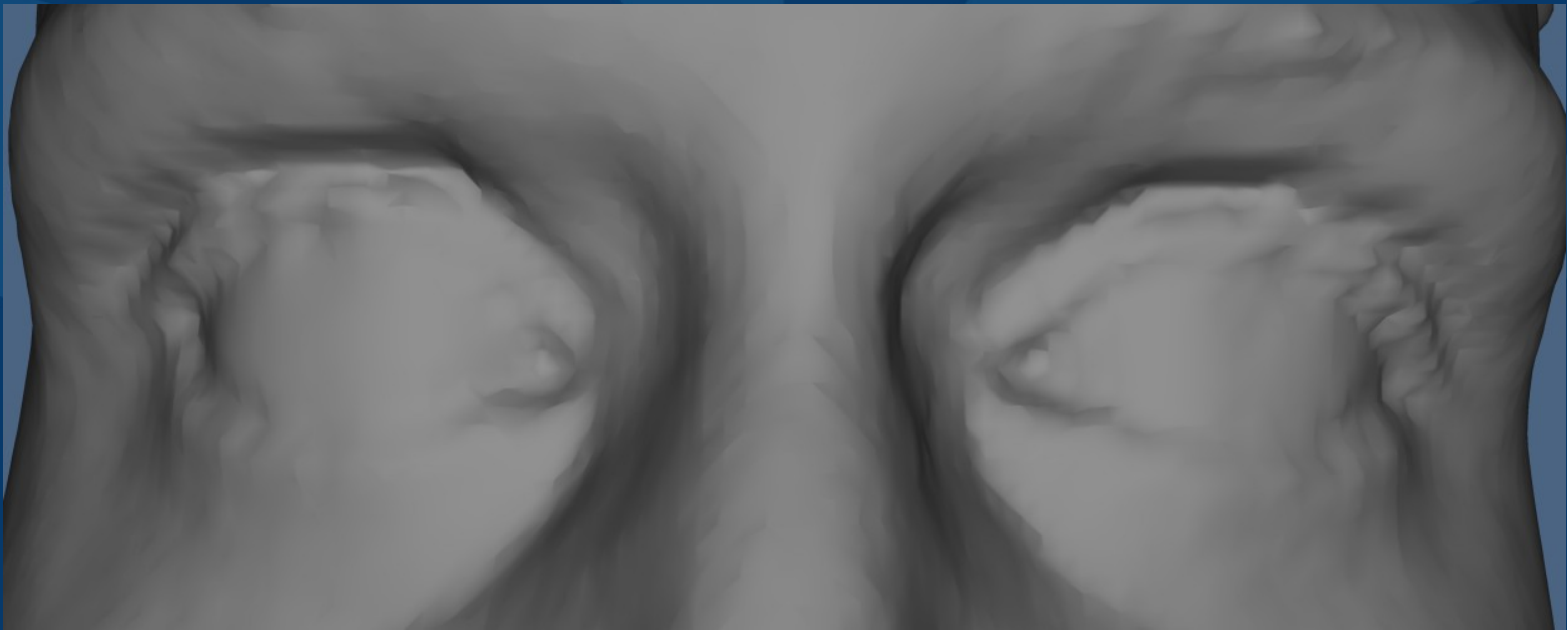


$$\Gamma_{smooth} = D_s(d)G(K)\alpha K$$

Localized Smoothing

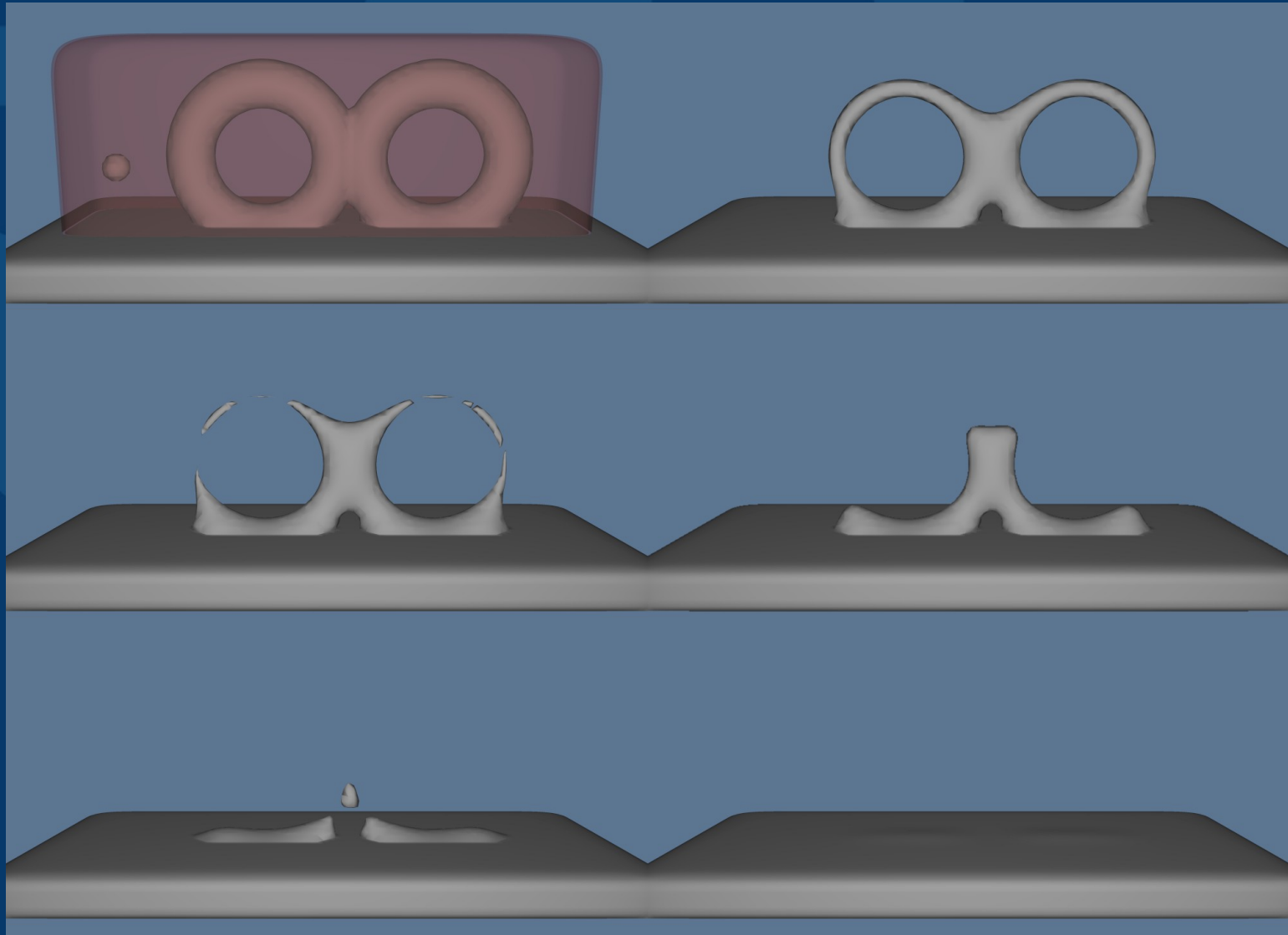
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Spikes in regions of smooth detail (error)



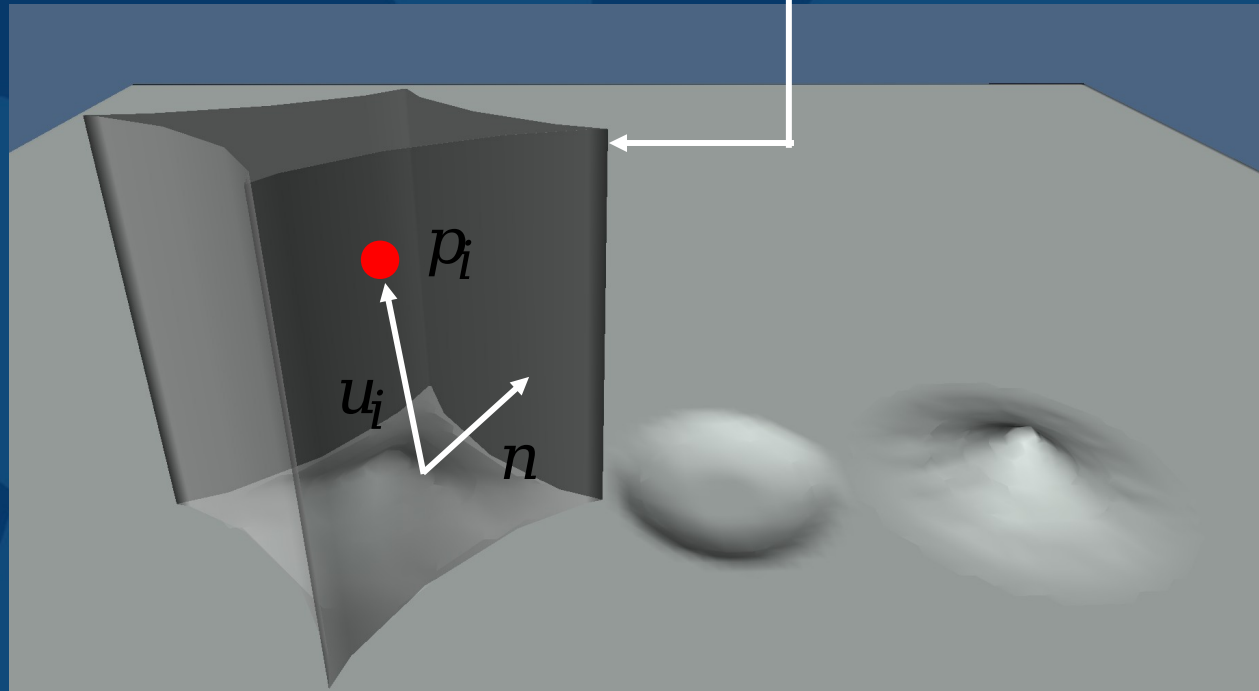
Topology Simplification

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Point Embossing

$$\Gamma_{emboss} = -\alpha \varphi(p_i, t) D_S(d) G(\pm n \bullet u_i)$$



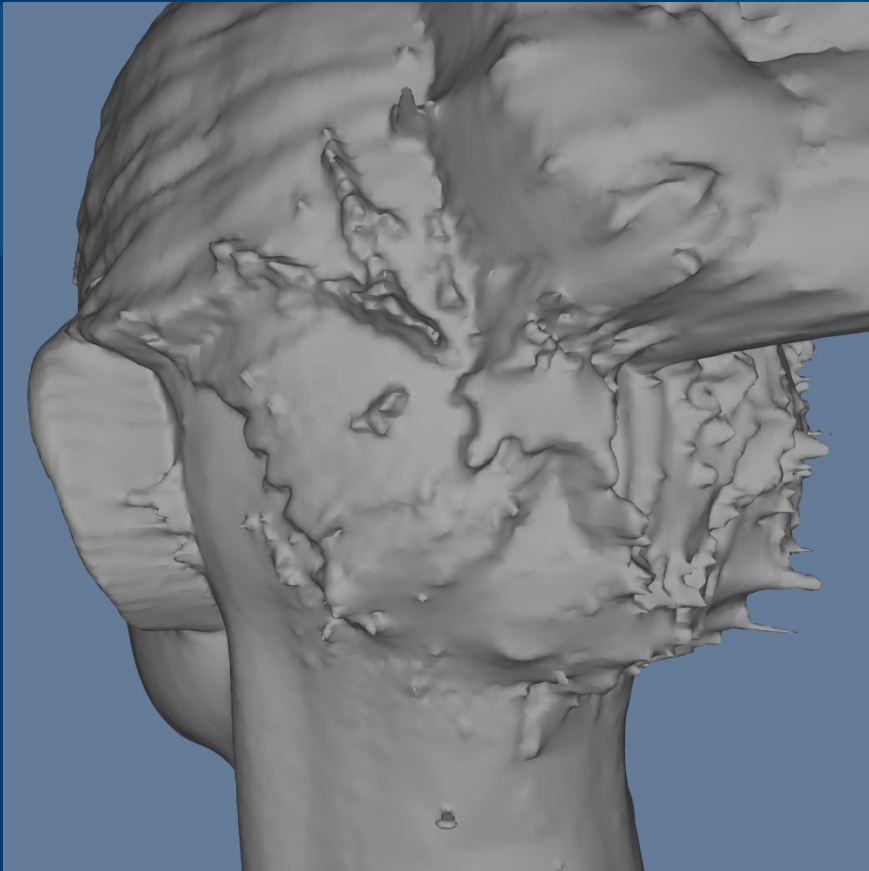
Point Embossing

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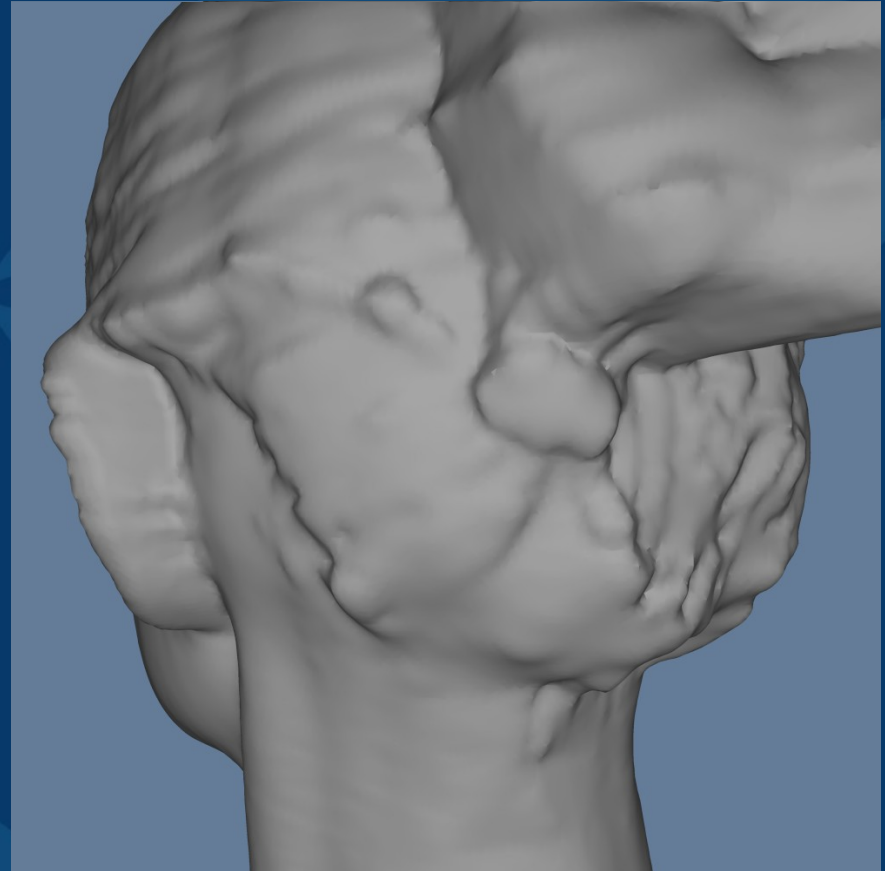


Global Smoothing with a Morphological Opening

Back of Female Head



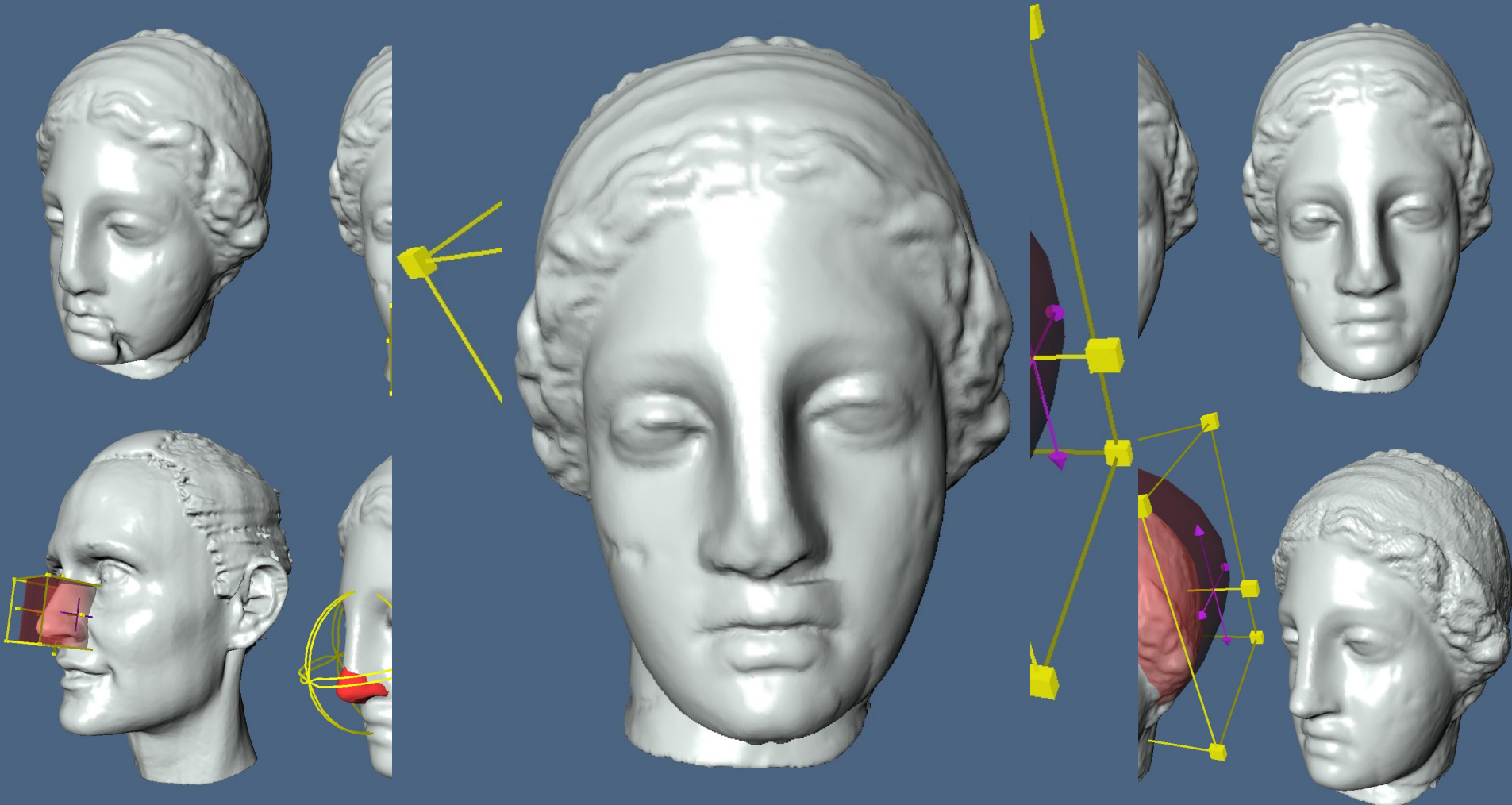
Erosion → Dilation



Repairing a Greek Bust

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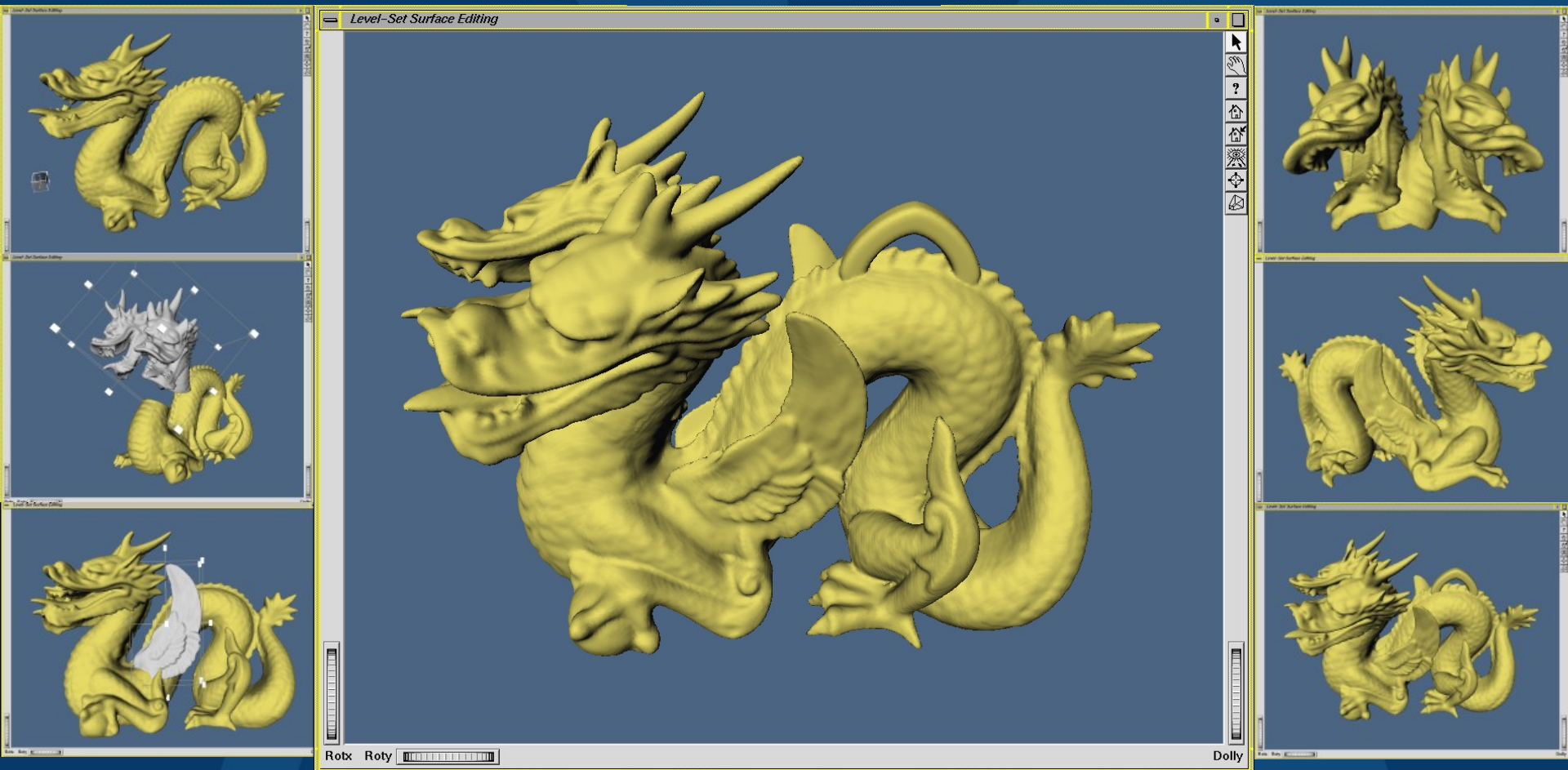
Computer Graphics (SIGGRAPH 2002)



Creating The Dragon

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AP1 Fantasy New World 4.0.0.0



Summary

- **Robust:** No self-intersections and allows for changing topology
- **Fast:** LS computations are regionally constraint
- **Simple:** Speed functions encode the editing operators on a single data structure
- **Closed:** Editing operation can be applied repeatedly
- **General:** Can import many types of geometric models

Future Work

- **Better representation of sharp features**
 - Implement adaptive Level Set methods
 - Improve mesh extraction
- **More control and operations**
 - Add control of topology
 - Add dragging, warping and sweeping
- **Improve rendering**
 - Incremental mesh extraction
 - Direct volume rendering

Acknowledgement

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